

UNITED STATES PATENT APPLICATION FOR:

DRILL SHOE

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DRILL SHOE

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims benefit of co-pending U.S. Provisional Patent Application Serial No. 60/450,432, filed on February 27, 2003, which application is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] Field of the Invention

[0003] Embodiments of the present invention generally relate to the field of well drilling, particularly to the field of well drilling for the extraction of hydrocarbons from sub-surface formations, wherein the drill string is used as the well casing.

[0004] Description of the Related Art

[0005] The drilling of wells to recover hydrocarbons from subsurface formations is typically accomplished by directing a rotatable drilling element, such as a drill bit, into the earth on the end of tubing known as a "drill string" through which drilling mud is directed to cool and clean the drilling face of the drill bit and remove drilled material or cuttings from the borehole as it is drilled. After the borehole has been drilled or bored to its desired depth and location, the borehole is typically cased, *i.e.*, metal tubing is located along the length of the borehole and cemented in place to isolate the borehole from the surrounding earth, prevent the formation from caving into the borehole, and to isolate the earth formations from one another. The casing is then perforated at specific locations where hydrocarbons are expected to be found, to enable their recovery through the borehole.

[0006] It is known to use casing as the drill string, and, when drilling is completed to a desired depth, to cement the casing in place and thereby eliminate the need to remove the drill string from the borehole. However, when casing is

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used in place of the drill string, any equipment or tooling used in the drilling of the well must be removed from the interior of the casing to allow an additional, smaller diameter casing and drill bit to drill the borehole further into the earth. Thus, the drill bit or drill shoe located at the end of the drill string must be eliminated as an obstacle, without pulling the casing from the borehole. Removal of the drill shoe is typically accomplished by drilling through the drill shoe with a second drill shoe or drill bit extended into the previously cemented casing, and thence into the earth beyond the just drilled drill shoe. Thus the drill shoe needs to be configured of a drillable material, which limits the loading which can be placed on the drill shoe during drilling and thus limits the efficiency of drilling with the drillable drill shoe. Typically a "drillable" drill shoe is configured of a relatively soft metal, such as aluminum, with relatively hard inserts of materials such as synthetic diamond located thereon to serve as the cutting material. Additionally, although the main body of the drillable drill shoe is configured of a readily drilled material, the hard cutters of the drill shoe tend to cause rapid wear and physical damage to the drill shoe being used to drill through the previous drill shoe, thus reducing the life of the drill bit, and thus the depth of formation the drill shoe can penetrate before it too must be drilled through by an additional drill shoe directed through the casing.

[0007] It is also known to provide a drill shoe having a relatively soft metal body, within which a plurality of stronger metal blades are received, upon which blades are supplied the cutters for cutting into the earth as the borehole progresses and which blades may be moved out of the area through which the drill shoe is drilled and subsequent casing penetrates, as is disclosed in United States Patent Number 6,443,247, assigned to the assignee of the present invention and incorporated by reference herein in its entirety. This drill shoe includes an integral piston assembly therein, which, upon actuation by a drilling operator, pushes through the drill shoe and physically presses the harder metal blades, with the cutters thereon, into the annular area and/or the adjacent formation and out of the area through which the next drill shoe will pass. Thereafter, an additional drill shoe is passed down the existing casing to remove the remaining, relatively soft, metal mass of the drill shoe, and into the formation

beyond the just drilled through drill shoe. Although this drill shoe configuration solves the problem encountered when the drill shoe would otherwise need to engage and grind up hard metal parts, the drill shoes still suffer from limited lifetimes because the blades will extrude or otherwise become separated from the relatively soft metal body of the drill shoe if the loading thereon exceeds a certain threshold. Thus, although this style of drill shoe has gained a high degree of commercial acceptance, the capability of the drill shoe remains limited.

SUMMARY OF THE INVENTION

[0008] The present invention generally provides methods and apparatus for drilling of boreholes, wherein the drill string is used as the casing for the borehole, wherein the drill shoe used for drilling the borehole includes an integral displacement element whereby the cutting elements of the drill shoe are displaceable into the formation surrounding the drill shoe when the well is completed. The drill shoe includes one or more blades having cutters thereon, and each of the blades includes an engagement profile for secure engagement with the body of the drill shoe during drilling operation yet is readily deformed to be embedded into the formation adjacent the drill shoe when drilling is completed.

[0009] In one embodiment, the blades include an outer axial section, a transverse section, and a generally axial base section that are received in a continuous slot formed within the body of the drill shoe. The slot and the blade include complementary profiles for maintaining the blades in position against the loading of the blades caused by the engagement thereof with the formation being drilled, while allowing the blades to be displaced into the formation after drilling is completed.

[0010] To enable displacement of the blades into the formation, the drill shoe preferably includes a passageway therein through which the drilling mud is flowed, and which is selectively blocked while the drilling mud is continued to be pumped into the drill string. The blocking of the mud passages completes a piston

structure, which is actuated through the drill shoe and thereby pushes the blades into the adjacent formation.

[0011] In another aspect, the present invention provides an earth removal apparatus comprising a first body portion and a second body portion at least partially receivable within the first body portion. A profile is formed on an outer surface of the second body portion and a cutting member is engaged with the profile, wherein the profile is adapted to maintain the cutting member on the profile during operation.

[0012] In another aspect, the present invention provides an earth removal apparatus comprising a drillable body portion and at least one profile formed on an outer surface of the drillable body portion. The at least one profile including at least two intersecting faces, wherein one of the faces includes a projection thereon. A blade is matingly engageable with the at least one profile.

[0013] In another aspect, the present invention provides a drill bit comprising a first body portion and a drillable second body portion. At least one profile is formed integral with at least one of the first body portion and the drillable second body portion, the at least one profile having at least two opposed segments having a discernable orientation. A cutting member is received in the at least one profile and having the discernable orientation and the discernable orientation including an included angle between the opposed segments of less than ninety degrees.

[0014] In another aspect, the present invention provides a method of drilling with casing, wherein a drillable drill bit is provided, comprising providing a drill bit support at a lower end of the casing, locating a drillable body portion within the drill bit support, and providing a blade receiving member integral with at least one of the drill bit support and the body portion. The receiving member including a profile. The method also includes positioning a blade having a mating profile on the receiving member and using the drill bit to form a wellbore, wherein the profile is adapted to substantially maintain the blade on the blade receiving member during drilling.

[0015] In another aspect, the present invention provides a method of completing a wellbore comprising providing an earth removal apparatus at a lower of a drill string. The earth removal apparatus having a first body portion and a drillable portion disposed in the first body portion, the drillable portion including a bore. The method also includes forming the wellbore, blocking the bore from fluid communication, moving the drillable portion relative the first sleeve portion, and re-establishing fluid communication between an inner portion of the earth removal apparatus and the wellbore.

[0016] In another aspect, the present invention provides a downhole valve comprising a first body portion, a bore disposed through the first body portion, and an obstruction member retainer at least partially disposed in the bore, wherein the obstruction member retainer is adapted to cooperate with an obstruction member to provide selective fluid communication through the bore.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0018] Figure 1 is a perspective view of a drill shoe of the present invention;

[0019] Figure 2 is a sectional view of the drill shoe of Figure 1 in a downhole location;

[0020] Figure 3 is a sectional view of the drill shoe of Figure 2, after the drill shoe has reached total depth and the drill shoe is prepared to be drilled through;

[0021] Figure 4 is a perspective view of a blade portion of the drill shoe of Figure 1;

[0022] Figure 5 is a sectional view of the blade portion disposed on the notch of the drill shoe;

[0023] Figure 6 is a further sectional view of the blade portion disposed on the notch of the drill shoe;

[0024] Figure 7 is a sectional view of the drill shoe as shown in Figure 2, after having been drilled through

[0025] Figure 8 shows another embodiment of a drill shoe according to aspects of the present invention;

[0026] Figure 9 shows yet another embodiment of a drill shoe according to aspects of the present invention; and

[0027] Figure 10 shows the drill shoe of Figure 9 after the ball has extruded through the ball seat to re-establish circulation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0028] Referring initially to Figure 1, there is shown in perspective an earth removal apparatus such as a drill shoe 10 of the present invention, for placement on the end of a string of casing for drilling a borehole into the earth, primarily for the recovery or potential recovery of hydrocarbons from sub-surface locations. The drill shoe 10 generally includes a support, such as a sleeve portion 20, into which is received a drillable member, such as a body portion 30, and over which are secured a plurality of cutting members or blades 26 (only four of a total of six to be so located) in notches 70 formed on the exterior of the drill shoe 10. The drill shoe 10 is specifically configured to enable the drilling of a borehole with the drill shoe 10, with subsequent cementing of the casing into the borehole, and then subsequent drilling through of the drill shoe 10 with a subsequent drill shoe 10.

[0029] Referring now to Figures 2 and 3, there is shown, in cross section, the drill shoe 10 of the present invention, suspended upon casing 12 located within a borehole 14, which casing 12 is rotated by a drilling table, top drive, or similar apparatus (not shown) at the earth's surface to enable the drill shoe 10 to drill or cut into the formations encountered thereby and thus form the borehole 14. The drill shoe 10 generally includes an outer, tubular sleeve 20 upon which a plurality of blades 26 are secured, and within which is positioned a body portion 30 of a drillable material, such as aluminum. In operation, the body portion 30 provides rigidity to prevent deformation of the sleeve 20 and maintain the drill shoe 10 on a threaded connection on the lower most extension of the casing in the wellbore as drilling operations are carried out, and also provides an extrusion element which may be pushed through the sleeve 20 and thereby push the blades 26 into the adjacent formation in the annular area and/or sides of the borehole 14 to enable drilling through of the drill shoe 10 during subsequent operations in the borehole 14.

[0030] Sleeve 20 is generally configured as a tubular or cylindrical element, and includes a first, threaded end 22 for threaded receipt upon the lowermost extension of the casing 12, an outer, cylindrical face 24 upon which a plurality of blades 26 (preferably 6) are disposed, and a lower open end 28. The inner cylindrical face of sleeve 20 includes a first, major diameter bore 34 extending from first end 22, and a second smaller diameter bore 36 extending from a ledge 38 formed at the intersection of these two, collinear, bores. Within sleeve 20 is received the body portion 30 of a drillable material, such as aluminum, which forms a mass within the sleeve to maintain the shape of sleeve 20 as the drill shoe 10 is pushed against the bottom 16 of the borehole 14 and rotated. Sleeve 20 further includes a plurality of mud vents 37, disposed radially through the sleeve 20 at the major diameter bore 34.

[0031] Body portion 30 is a generally right circular mass of drillable material, having features formed therein such as by machining, to provide a mass of material to back up the relatively thin wall of the sleeve 20 during drilling, to enable the extrusion of the body portion 30 through any potentially borehole

interfering sections of the sleeve 20 and the blades 26 when the drilling is completed with the drill shoe 10, and to provide a readily drillable material for removal of the mass from the borehole 14. Body portion 30 generally includes a main counterbore 40 extending inwardly of the first end 42 thereof, and ending at a generally conically concave base 44 from which a mud bore 46 extends inwardly of the backup portion of body portion forming backup mass to limit the deformation of the sleeve 20 and the blades 26 during drilling operations. Mud bore 46 splits into a plurality of mud passages 50, which terminate at the lower surface of the body portion 30. Mud bore 46 also includes a tapered seat portion 52, into which a ball 51 (Figure 2) may be seated, as will be further described herein. The outer surface of body portion 30 includes a generally right circular outer face 54, and an end portion 56 which is profiled and machined to receive a portion of the blades 26 therein, as will be described further herein. Outer face 54 includes, at the opening of the counterbore 40, a outwardly extending lip 58 which sealingly, or at least is substantially closely, fits to the inner face of major diameter bore 34, as well as at least one axial slot 60, extending along the outer face 54 from the end portion 56. A pin 62 is secured within sleeve 20 and extends into slot 60, and serves to prevent rotation of the body portion 30 within sleeve 20 when a different drill bit introduced down the casing interior drills the body portion 30 out.

[0032] To retain the body portion 30 within sleeve 20, the sleeve 20 includes a retainer ring 64, located within major diameter bore 34 generally above the body portion 30 and secured thereto with pins or the like, which prevents retraction of the body portion 30 from the sleeve 20, and an inwardly projecting lip 66, extending inwardly at the lower open end thereof, which is received into an annular recess 68 machined or cast into the face of body portion 30 about its perimeter (best shown in Figure 3). Lip 66 may be a continuous inward projection on the end of the sleeve 20, or may be a separate retainer ring which is affixed at its inboard end to the end of sleeve 20.

[0033] Referring again to Figure 1, a general overview of the structure of the blades 26, as well as their attachment to the drill shoe 10, is shown. Generally, the blades 26 are received within a profile which extends along the outer surface

of the sleeve 20 and the base of body portion 30. An exemplary profile is a notch 70 configured to interact with the blade 26 to keep the blade 26 in position on the sleeve 20 during drilling operation. Each blade 26 is formed of a single length of steel, or similar material having both relatively high strength, rigidity and ductility, bent to form opposed first and second linear sections 72, 74, which are interconnected by curved shoulder segment 76. A plurality of cutters 78 are located on the outer face of the blades 26, to be engaged with, and cut into, the formation as the borehole extends therein. Although six blades 6 are shown in the Figures, it is contemplated that any suitable number of blades 26 may be disposed on the drill shoe 10. For example, the drill shoe 10 may include four blades or five blades.

[0034] The interface and interconnection of the blade 26 and notch 70 is shown in detail in Figures 5 and 6, wherein the blade 26 is generally rectangular in cross section, and includes a multifaceted base 80 which contacts a multifaceted first face 82 of the notch 70, and a sidewall 84 which abuts against a second face 86 of the notch 70. Multifaceted base 80 includes a centrally located, generally rectangular, slot 88 extending therein over the length thereof, into which a mating rectangular projection 90 of the notch 70 extends, along the entire length of the blade 26. Projection 90, being generally rectangular in cross section, forms in conjunction with multifaceted first face 82 a first compression face 104 extended upwardly on projection 90, and first and second lower compression faces 106, 108, disposed to either side of first compression face 104, an anti-rotation flank 100 in facing relationship to second face 86 of notch 70, and a secondary abutment face 93, on the opposed flank of the projection from anti rotation flank 100 and generally parallel thereto and to second face 86 of the notch 70.

[0035] Referring again to Figure 1, to create the multifaceted notch 70, a continuous groove (not shown) is cut into the outer face of both the sleeve 20 and body 30, into which preforms 112 and 114, having the specific geometry of the notch 70 provided therein, are inserted and welded into place. Alternatively, the preform 114 in body portion 30 may be created by directly molding a boss into the body portion 30 when the body portion 30 is initially configured such as by

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aluminum casting, and then machining the specific geometry of the notch 70 therein. Alternatively still, the preforms 112, 114 may be formed into both the sleeve 20 and the body portion 30 by machining. Additionally, the outer surface of the sleeve 20 includes stabilizers or standoffs 132, positioned at the uppermost terminus of the notch 70, having a height corresponding generally to the height of the cutters 78 on the first linear section 72 of the blades 26, to center or stabilize the drill shoe 10 in the borehole 14.

[0036] Referring now to Figures 5 and 6, the blade 26 includes geometry complimentary to the notch 70, such that slot 88 projecting into multifaceted base 80 creates a multi level engagement surface, including a recessed face 91 and two extended faces 92, 94, generally parallel thereto and extended therefrom by the depth of the slot 88, as well as first projecting face 96 and second projecting face 98, formed as the flanks of the slot in a facing, generally parallel relationship to one another and to the sidewall 84. The depth of slot 88 is variable, such that the slot 88 is deeper, and thus the area of faces 96 and 98 are greater, in second linear section 74 of the blade 26 which, in use, is located within the notch 70 received in the body portion 30 of the drill shoe 10. Likewise, as shown in Figure 5, the height of sidewall 84 is increased to maintain a larger area for full depth contact between sidewall 84 and second face 86. As it is specifically contemplated that the body portion 30 is configured from an easily drillable material, which will likely have a lower shear or yield resistance than the material used for the sleeve 20, this larger area of the faces (and correspondingly of sidewall 84) helps distribute the load in the notch 70 over a greater area in the body portion 30 as compared to the sleeve 20, and thereby reduce the likelihood of plastic failure of the notch 70 as it extends in the body portion 30 under drilling conditions. As shown in Figures 5 and 6, the aspect ratio of the slot 88 (and correspondingly in the mating surfaces of the notch 70), and likewise of the projection 90, defined as the height of the projection (or depth of slot) to its width, ranges in the embodiment shown from slightly over 1:1 at the first linear section 72 of the blade 26, to approximately 2:1 at the second linear section 74 of the blade 26. It is contemplated that higher aspect ratios are appropriate, for

example, where the blade is very large in width, *i.e.*, the circumferential direction of the sleeve 20, for example on the order of 5 inches wide, a slot depth of only 0.010 inches may be appropriate, resulting in an aspect ratio of 0.002:1. Likewise, were the blade made relatively tall, a high aspect ratio on the order of 500:1 may be appropriate.

[0037] Received upon the outer surface of the blade 26 are a plurality of cutters 78, typically hardened synthetic diamond compacts, which are attached thereto using welding, high strength adhesives, threaded engagement into bores in the blade 26, or the like. To secure the blade 26 and fill the gaps or clearances between the blade 26 in the notch 70, adhesive or filler, such as Tubelok available from Weatherford Corporation of Houston, Texas, is applied to the blade 26 and notch 70, and the blade 26 pushed therein. It is specifically contemplated that the fit of the blade 26 in the notch 70 not be an interference fit at ambient temperatures, and that a clearance on the order of a few thousands of an inch between the slot 88 and projection 90 is allowable as long as the fit is snug.

[0038] During drilling operation, the drill shoe 10 rotates generally about axis 120 (Figure 2) such that, as shown in Figure 5, the blade 26 moves in the direction of arrow 122 into engagement with the formation. As a result, force will be imparted against the blade 26 as shown by arrow 124, tending to cause the blade 26 to rotate (or load in the notch 70) as shown by arrow 126. The configuration of the blade 26 and notch 70 are specifically provided to prevent such motion. Thus, as this loading occurs, sidewall 84 is pushed against second face 86 of the groove, and first projecting face 96 bears against secondary abutment face 93 of groove, to provide lateral or direct support against the primary load of the formation, simultaneously, second projecting face 98 is coupled, by the moment caused by the loading of the blade 26 at the cutters 78, against anti-rotation flank 100, and each of the faces 91, 92 and 94 of the blade 26 are loaded by the moment against their respective compression faces 104, 106 and 108, thereby preventing significant movement of the blade 26 in the notch 70. Thus, as force is imparted against the blade 26 in the direction of the arrow 126, any tipping or rotation of the blade 26 will be absorbed by the notch 70. To secure the blade

26 on the sleeve 20, the blade 26 is welded thereto at one or more locations along its length.

[0039] The blade geometry, in addition to the blade profile helps maintain the blade 26 on the sleeve 20. During drilling operations, it is unlikely that the entire length of a blade 26 will be simultaneously engaged against the formation. Furthermore, the presence of standoffs 132 on the sidewall of the sleeve 20 limits the penetration of the cutters 78 on the first linear section 72 of the blade 26. Thus, when the drill shoe 10 is pushing against the bottom of the borehole 14, the second linear section 74 of the blade 26 will be engaged with the formation, whereas the other portions may not. Thus, force will be imparted against the second linear section 74 of the blade 26, tending to cause it to tip or rotate in the notch 70 in the direction of arrow 126 (Figure 5). However, it can be seen from Figure 4 that the geometry of the blade 26 results in the first linear section 72 and curved segment 76 being levers, with respect to the second linear section 74, and the placement of these portions of the blade 26 within the notch 70 will cause these portions of the blade 26, along with the structural rigidity of the blade 26, to help the blade 26 resist rotating out of the notch 70. Additionally, the included angle 136 between the two linear sections 72, 74, is preferably maintained below 90 degrees, which further enhances the likelihood of maintaining the blade 26 in the notch 70. As the outer face 138 of the blade 26 is preferably parallel with the recessed face 91 and two extended faces 92, 94 of the blade 26 which rest at compression faces 104, 106 and 108 of the notch 70, the included angle 136 is repeated between these faces as well.

[0040] Referring again to Figures 2 and 3, the operation of the drill shoe 10 for using the casing 12 as drill string is shown. Specifically, when the borehole 14 has reached total depth for the specific drill shoe 10 in use, which is a function of the wear of the drill shoe 10, the casing 12 is pulled upwardly in the borehole 14, to leave a space between the drill shoe 10 and the bottom of the hole 14 as shown in Figure 2. In this position, drilling mud continues to flow down the middle of the casing 12, and thence outwardly through the mud passages 50 in the drill

shoe 10 and thence to the surface through the space between the drill shoe 10 and casing 12 and the borehole 14.

[0041] To begin the operation ultimately leading to the elimination of the drill shoe 10 as an obstacle in the borehole 14, a ball 51 is dropped through the casing 12 into the mud bore 52 from a remote location, which can include the earth's surface. When the ball 51 enters the mud bore 52, it seals the mud bore 52 causing the mud to press down upon the body portion 30, and causes the body portion 30 to slide within sleeve 20 from the position of Figure 2 and Figure 3. As the body portion 30 begins to slide, it deforms the base of sleeve 20 outwardly, and also deforms the second section 74 about the angled portion 76 of the blade 26 such that the blades 26 are bent into a generally linear condition as shown in Figure 3. In one embodiment, the second section 74 may be embedded within the walls of the borehole along with the likewise deformed base of the sleeve 20. In another embodiment, it may be that a clearance exists between the wall of the borehole and the second section 74. Movement of the body portion 30 within the sleeve 20 to the position shown in Figure 3 also exposes the mud vents 37 to the drilling mud, thereby providing a new path for mud flow to re-establish circulation. In this respect, the new path may be used to introduce cement into the borehole to cement the casing 10. In one embodiment, cement may be supplied through the mud vents 37 to cement at least a portion of the casing 10 into place. Additionally, re-establishing the new path also causes a pressure drop in the mud column, which indicates to the operator that the body portion 30 successfully moved within the sleeve 20 to bend the blades 26 outwardly. Thereafter, a subsequent drill bit or drill shoe is passed down the casing 12, and is engaged into body portion 30 to drill through body portion and continue the drilling of the borehole 14 to further depth as shown in Figure 7.

[0042] Figure 8 presents another embodiment of the drill shoe according to aspects of the present invention. The drill shoe 10 includes a sleeve 220 having a body portion 230 disposed therein. The body portion 230 comprises a support sleeve 235 and an inner portion 240. The inner portion 240 may include components such as the ball seat 252 and the inner core 245. In one

embodiment, the ball seat 252 and the inner core 245 may be two separate components, as shown in the Figure. In another embodiment, the inner portion 240, *e.g.*, the ball seat 252 and the inner core 245, may be manufactured in one piece, as shown in Figure 2. Preferably, the inner portion 240 comprises a drillable material such as aluminum, and the support sleeve 235 comprises steel or other composite material of sufficient strength to provide rigidity to the body portion 230.

[0043] Figure 9 presents another embodiment of the drill shoe 10 according to aspects of the present invention. As shown, the drill shoe 10 provides an alternative method of re-establishing circulation. The drill shoe 10 includes a body portion 330 disposed in an outer sleeve 320. One or more blades are disposed on the outer surface of the outer sleeve 320 and the lower surface of the body portion 330. The body portion 330 includes a bore 346 which splits into one or more passages for fluid communication with the borehole 14. The bore 346 may include an obstruction member retainer for retaining an obstruction member. For example, the bore 346 may include a ball seat 352 for receiving a ball 351. Preferably, the ball seat 352 comprises a flexible material such that the ball 351 may be pumped through the ball seat 352 when a predetermined pressure is reached. The bore 346 also includes a biasing member 360 such as a spring 360 disposed below the ball seat 352. The spring 360 may be used to bias the ball 351 against the ball seat 352 to act as a valve to regulate fluid flow in the bore 346. Although a ball seat is disclosed, other types of obstruction member retainer known to a person of ordinary skill in the art are contemplated, for example, an obstruction member retainer having a seating surface for receiving an obstruction member to regulate fluid flow.

[0044] Figure 9 shows the drill shoe 10 after drilling has completed and the body portion 330 has deformed the base of the sleeve 320 outwardly. Particularly, a ball 351 landed in the ball seat 352 to allow pressure build up, thereby causing the body portion 330 to slide downward relative to the sleeve 320. As a result, the second section of the blades is bent into a generally linear condition.

[0045] To re-establish circulation, pressure above the ball 351 is increased further to pump the ball 351 to through the flexible ball seat 352, as shown in Figure 10. The ball 351 lands on the spring 360, which biases the spring 360 against the lower portion of the ball seat 352, which acts as a second seating surface for the ball 351. In this respect, a seal is formed between the ball 351 and the ball seat 352, thereby closing off fluid communication.

[0046] When the pressure of the cement or other fluid in the casing 12 is greater than the biasing force of the spring 360, the ball 351 may be caused to disengage the ball seat 352, thereby opening up the bore 346 for fluid communication with the borehole 14. In this manner, cement may be supplied to cement the casing 12 in the borehole 14. After the cementing operation is completed, pressure in the casing 12 is relieved. In turn, the spring 360 is again allowed to bias the ball 351 against the ball seat 352, thereby closing off the bore 346 for fluid communication. In this respect, the ball 351 and the ball seat 352 may act as a check valve to prevent cement or other fluid to re-enter the casing 12.

[0047] Although the invention has been described herein with respect to a specific embodiment, these embodiments may be modified without affecting the scope of the claims herein. In particular, the groove and slot configuration may be modified. For example, the slot may be positioned in the groove and the blade may include the projection, or alternatively, several slots and mating projections may be provided.

[0048] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.